27th URSI – General Assembly, 17-24 Aug 2002, Maastricht, The Netherlands
Commission G2 (D.Bilitza) – Operational ionospheric models including data ingestion

OPERATIONAL MODEL FOR REAL-TIME RECONSTRUCTION OF THE ELECTRON DENSITY PROFILE USING GPS TEC MEASUREMENTS

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The propagation delays in GNSS, introduced by the ionosphere, can be estimated and corrected much easier if the (vertical) electron density profile is available at a given location on a real-time basis. As the theoretical ionospheric models are not sufficiently good for the purpose, actual measurements, immediately available, should be considered. Presented is an operational procedure for a real-time reconstruction of the vertical electron density profile from concurrent GPS TEC and ionosonde measurements.

The on-line ionosonde measurements are used primarily for the reconstruction of the bottom-side electron density profile. The ionospheric profiler for the lower side (below hmF2) is based on the Epstein layer functions using the critical frequencies, foF2 and foE, and the propagation factor $M_{3000}F2$. The corresponding bottom-side part of the total electron content is calculated from this profile and then is subtracted from the GPS-measured TEC in order to obtain the unknown topside (above hmF2) electron content.

The above-mentioned ionosonde data, together with the simultaneously-measured TEC and empirically obtained O^+-H^+ transition level, are required for determination of the topside electron density distribution. The topside electron profile is considered as a sum of the constituent oxygen and hydrogen ion profiles which have unknown scale heights. In order to obtain these unknown scale heights, new formulae of the ion density profiles above the peak height are introduced. The formulae are based on the sech-squared, exponential, and Chapman layers and depend also on the O^+ and H^+ scale heights and the O^+-H^+ transition level. Both scale heights have a ratio 1:16 reduced by a factor representing the change from magnetic field line direction to vertical direction. To obtain the density distribution on the vertical direction, z , we use the simple conversion $dz = \sin I \, ds$, where ds is the differential element along the field lines, I is the inclination. If we ignore the displacement of the geographic and magnetic poles, then $dz = \sin[\mathrm{arctg}(2\mathrm{tg}\varphi)]ds$, where φ is the latitude. It is important that the resulting topside electron density distribution has variable scale height, and the crucial information for this variability comes from measurements of the ion transition height where the largest change in the electron density gradient occur.

The upper transition level is determined from an empirical model based on satellite and rocket in-situ measurements of the individual ion densities. In this model, the transition level is approximated by a multi-variable polynomial, providing convenience when referencing the level with respect to solar activity, season, local time, longitude and latitude.

The reconstruction procedure is demonstrated and tested on actual GPS TEC and ionospheric TEC calculated from ground-based ionosonde measurements. All digital ionosonde and TEC data are obtained at the Dourbes Geophysics Centre of the Royal Meteorological Institute of Belgium. At this center, a GPS receiver is collocated with a digital ionosonde, capable of producing GPS-based TEC values every 15 minutes. The GPS TEC measurements have been conducted since 1994 and a large database created for the best part of the current solar activity cycle.

Profile reconstruction can be performed at any location for which TEC measurements are available but the quality increases significantly if ionosonde data are also available near this location. Established numerical and observational methods are utilized when developing this operational model. It has the capability to be used, on a real-time basis, for estimating the propagating delays in GNSS, for developing/testing theoretical and empirical models, and also for addressing numerous space weather problems.